

Update on CMS PFlow Hadron Reco Performance in HGC

Sean Kalafut (Minnesota), Lindsey Gray (FNAL), Frank Chlebana (FNAL),
Roger Rusack (Minnesota), Maksat Haytmyradov (University of Iowa), Manqi
Ruan (CERN), Virginia Azzolini (Carnegie-Mellon), Tongguang Cheng (IHEP)

Agenda

- Pi+ and Neutral K_long Energy Linearity and Resolution using PFCluster objects
 - Data samples
 - PF object hierarchy
 - Why use PFClusters?
 - Calculating reconstructed energy
 - Hadron energy linearity curves
 - Hadron energy resolutions
 - Summary and future work

Pi+ Samples



- Single pi+ gun events shot with gen energies = 5, 10, 20, 40, 100, 200, 500, 1000 GeV at several gen etas
 - Eta = 1.75, 2.0, 2.25, 2.5, 2.9
 - At least 1000 events at each (gen energy, gen eta) point
- Generated with HGCalV4Muon geometry, using CMSSW_6_2_0_SLHC16 and jumping muons fix
 - NOT including neutron moderator fix
- Reconstruction uses HGC-Linking code to make RECO PF objects; code available through
https://twiki.cern.ch/twiki/bin/viewauth/CMS/HGCalPF_Reconstruction

K0L Samples

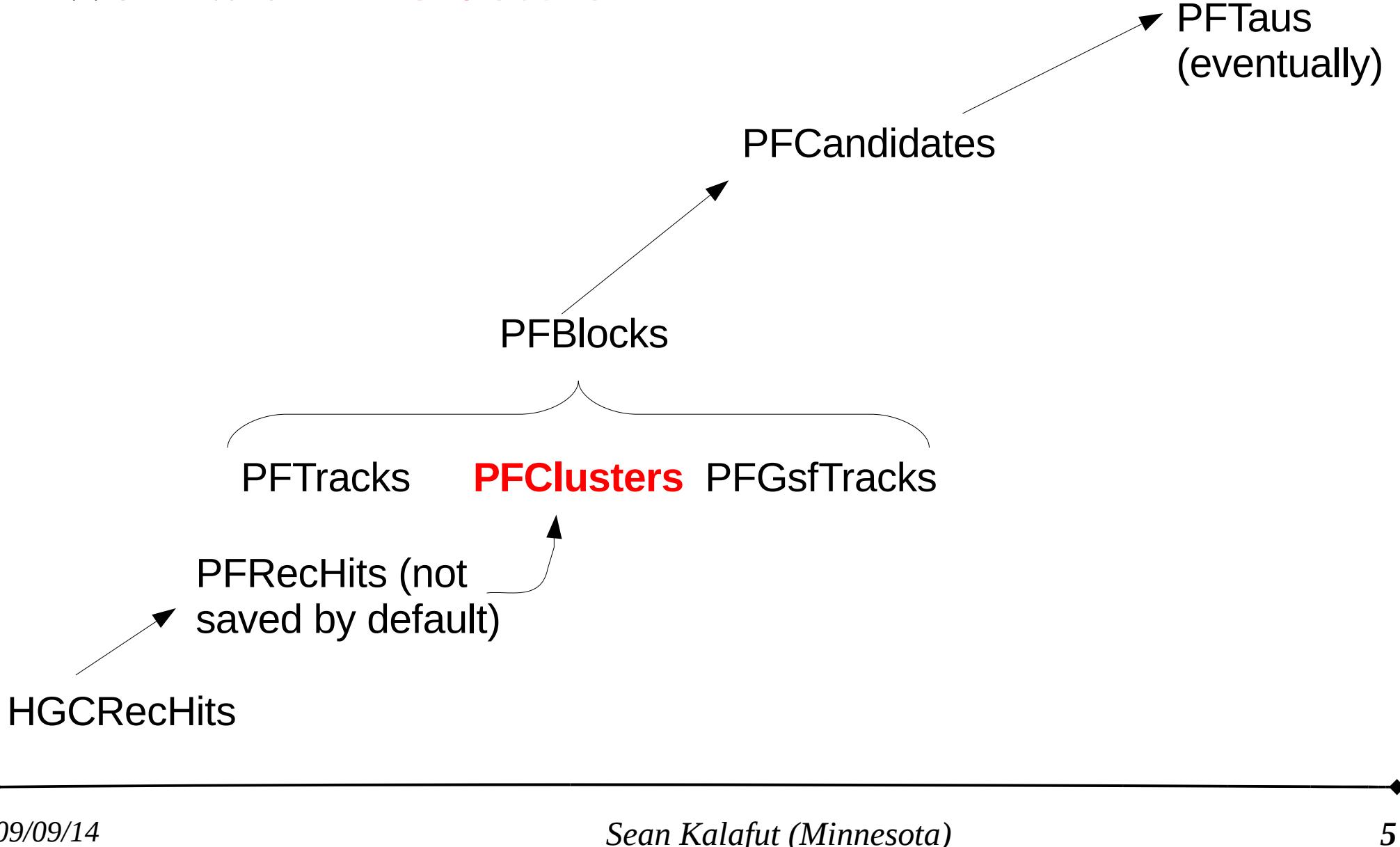


- Single K0L gun events shot with gen energies = 5, 10, 20, 40, 100, 200, 500, 1000 GeV at several gen etas
 - Eta = 1.75, 2.0, 2.25, 2.5, 2.9
 - ~1000 events at each (gen energy, gen eta) point
- Generated with HGCalV4Muon geometry, using CMSSW_6_2_0_SLHC16 and jumping muons fix
 - NOT including neutron moderator fix

Ideal Reco Object for Studies



- Work with **PFClusters**



Why Use PFClusters



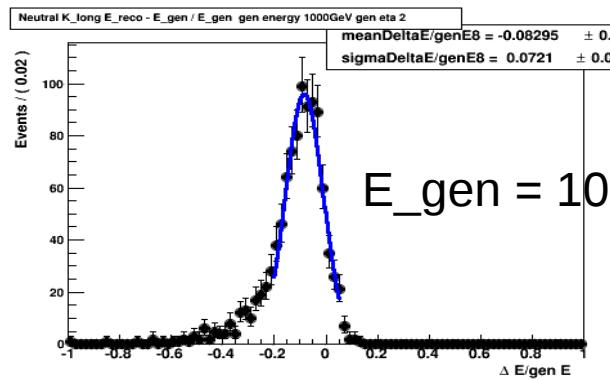
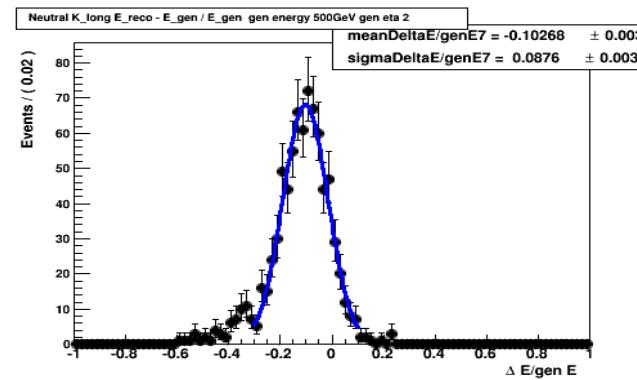
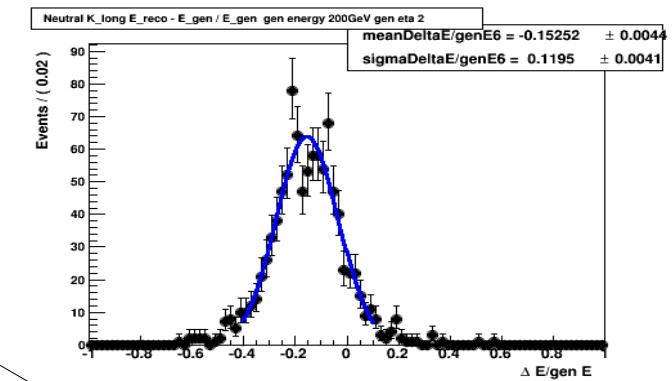
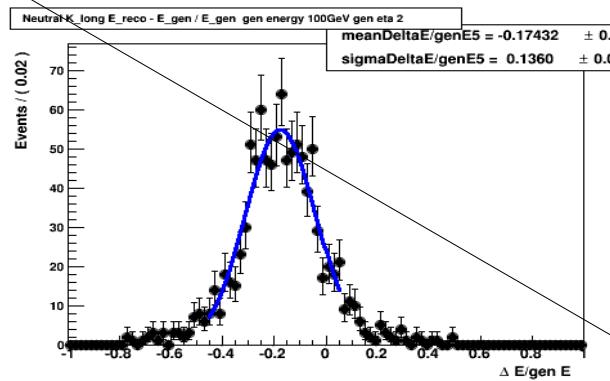
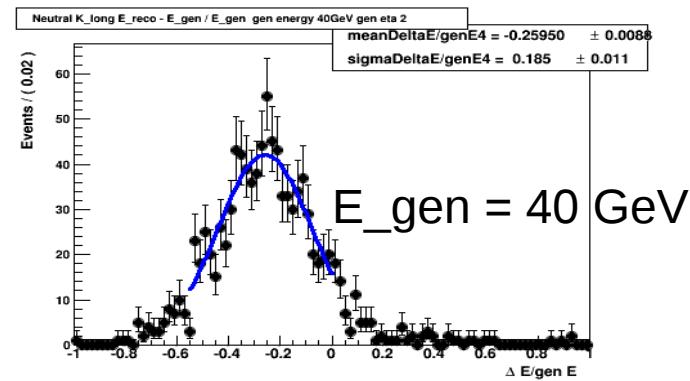
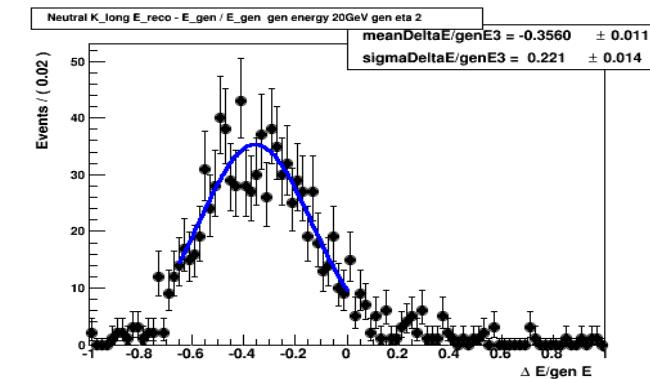
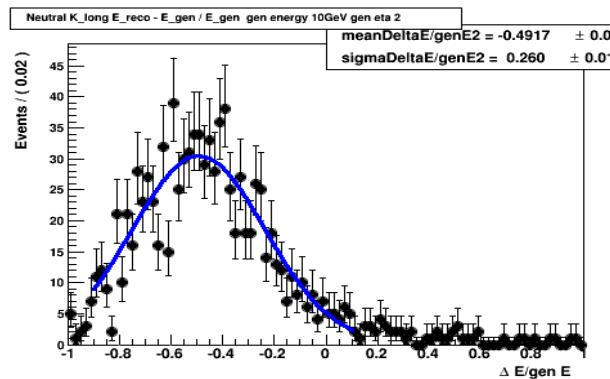
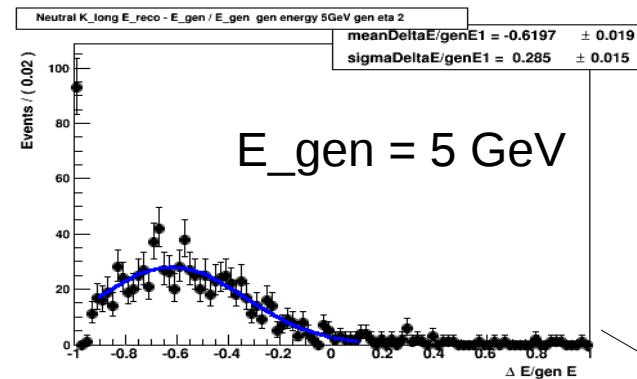
- PFClusters represent energy deposits measured by HGC alone
- Several PFCandidates can point to the same PFCluster
--> sum of PFCandidate energies will occasionally double count raw energy deposits

Calculating Reco Energy



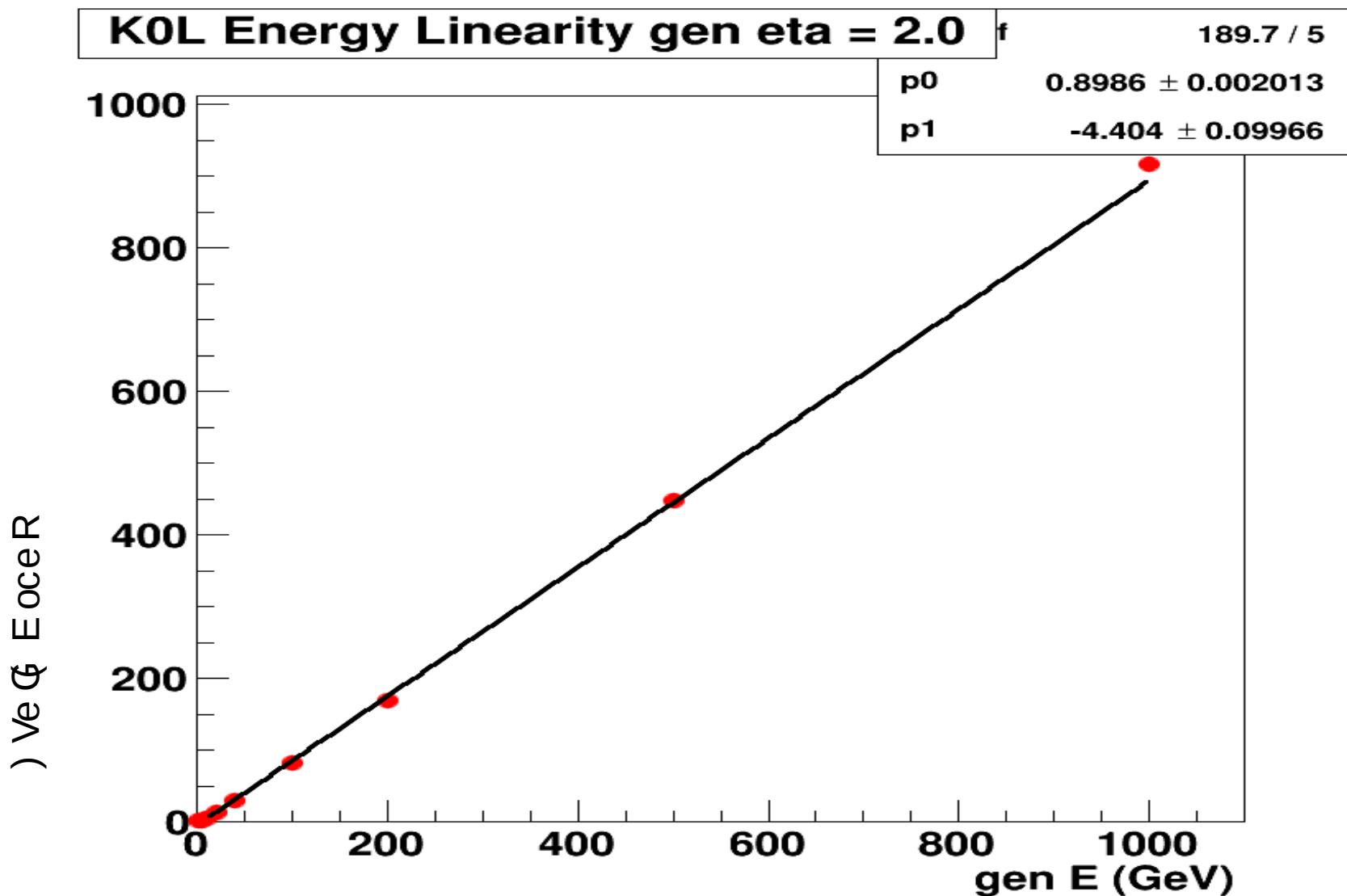
- In each event
 - Take all PFClusters in HGC with $pT > 0.1 \text{ GeV}$
 - Sum the energy of all PFClusters in HGC passing pT cut
- Summed PFCluster energy = E_{reco}
- Calculate $(E_{\text{reco}} - E_{\text{gen}})/E_{\text{gen}}$ for each event, make histograms of this value for different generator energy and generator eta

K0L $(E_{\text{reco}} - E_{\text{gen}})/E_{\text{gen}}$



Increasing E_{gen}
 All at gen eta = 2.0

K0L Energy Linearity

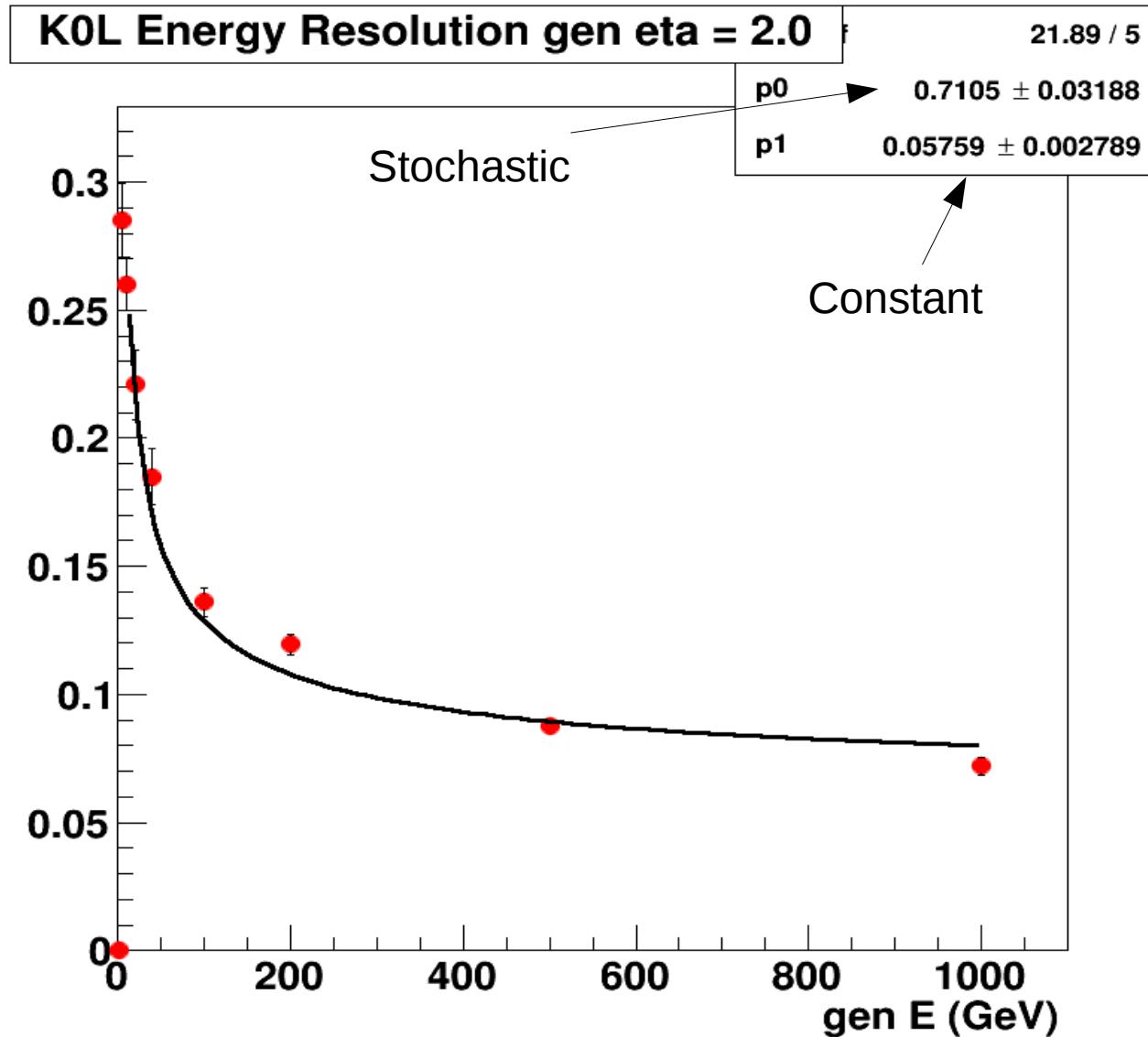


K0L Energy Linearity



Generator eta of neutral K_long	Energy scaling (slope) (%)	Reco energy offset (intercept) (GeV)	Fit chi^2/NDF that determines E scaling
1.75	89.9 +/- 0.2	-3.99 +/- 0.10	119./5
2.0	89.9 +/- 0.2	-4.40 +/- 0.10	190./5
2.25	89.7 +/- 0.2	-4.94 +/- 0.11	170./5
2.5	87.8 +/- 0.2	-4.86 +/- 0.12	286/5
2.9	81.1 +/- 0.35	-7.85 +/- 0.28	64.1/4

K0L Energy Resolution

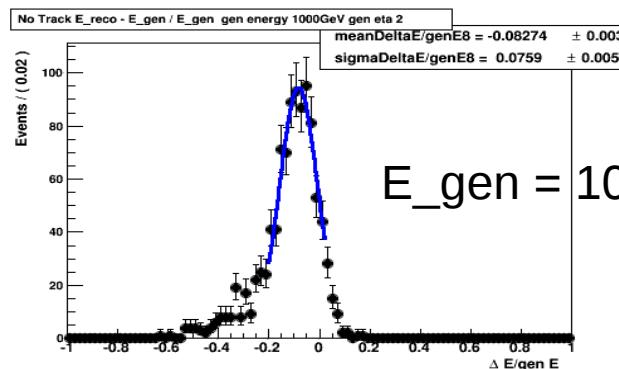
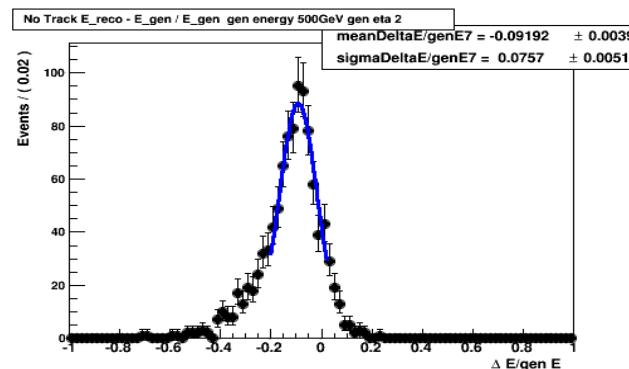
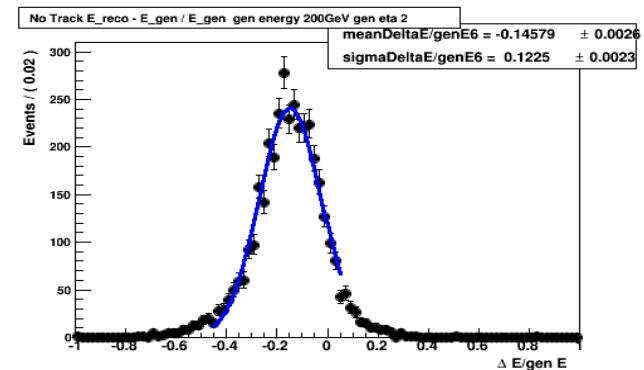
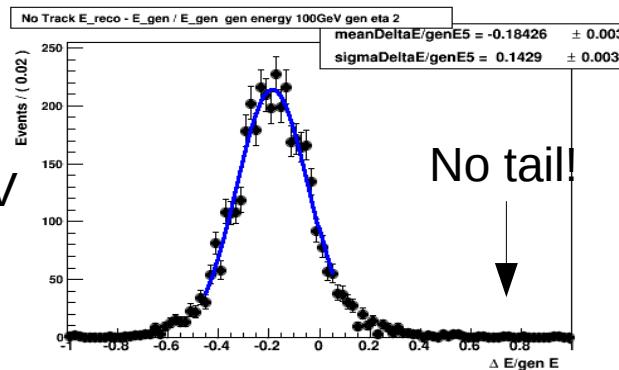
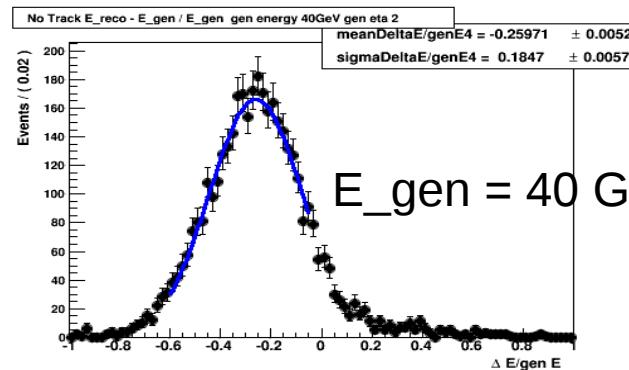
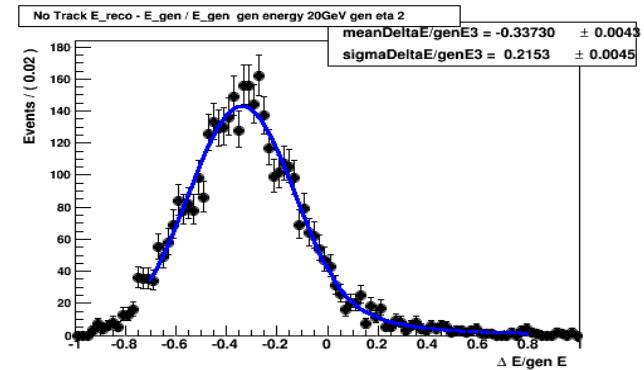
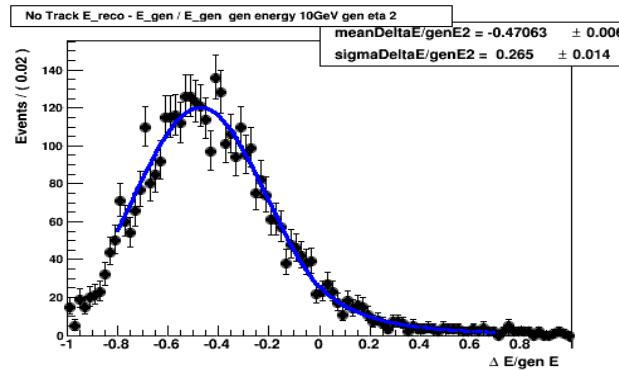
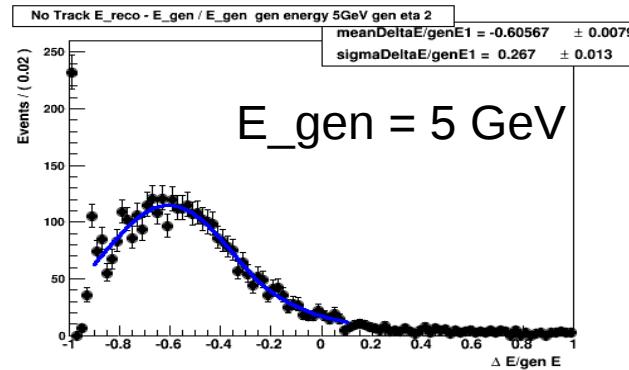


K0L Energy Resolution



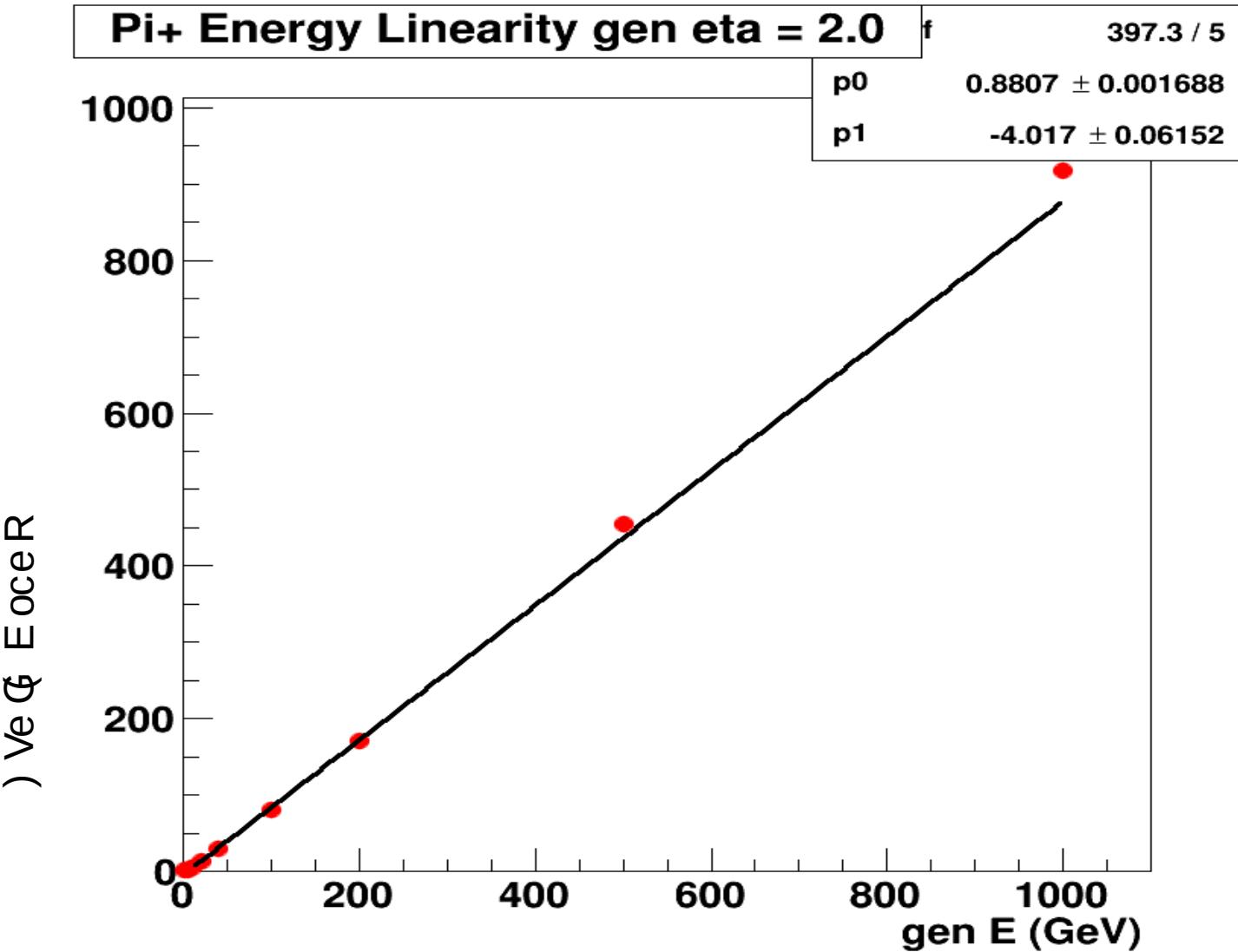
Generator eta of neutral K_long	Stochastic energy resolution (%)	Constant energy resolution (%)	Fit chi^2/NDF that determines E resolution %
1.75	65.2 +/- 3.6	7.05 +/- 0.34	10.2/5
2.0	71.1 +/- 3.2	5.76 +/- 0.28	21.9/5
2.25	70.0 +/- 3.1	5.42 +/- 0.27	28.0/5
2.5	77.7 +/- 3.9	5.71 +/- 0.41	22.8/5
2.9	109.8 +/- 6.4	5.51 +/- 0.64	2.43/4

$\text{Pi}^+ (\text{E}_\text{reco} - \text{E}_\text{gen})/\text{E}_\text{gen}$



GEN ETA = 2.0

Pi+ Energy Linearity

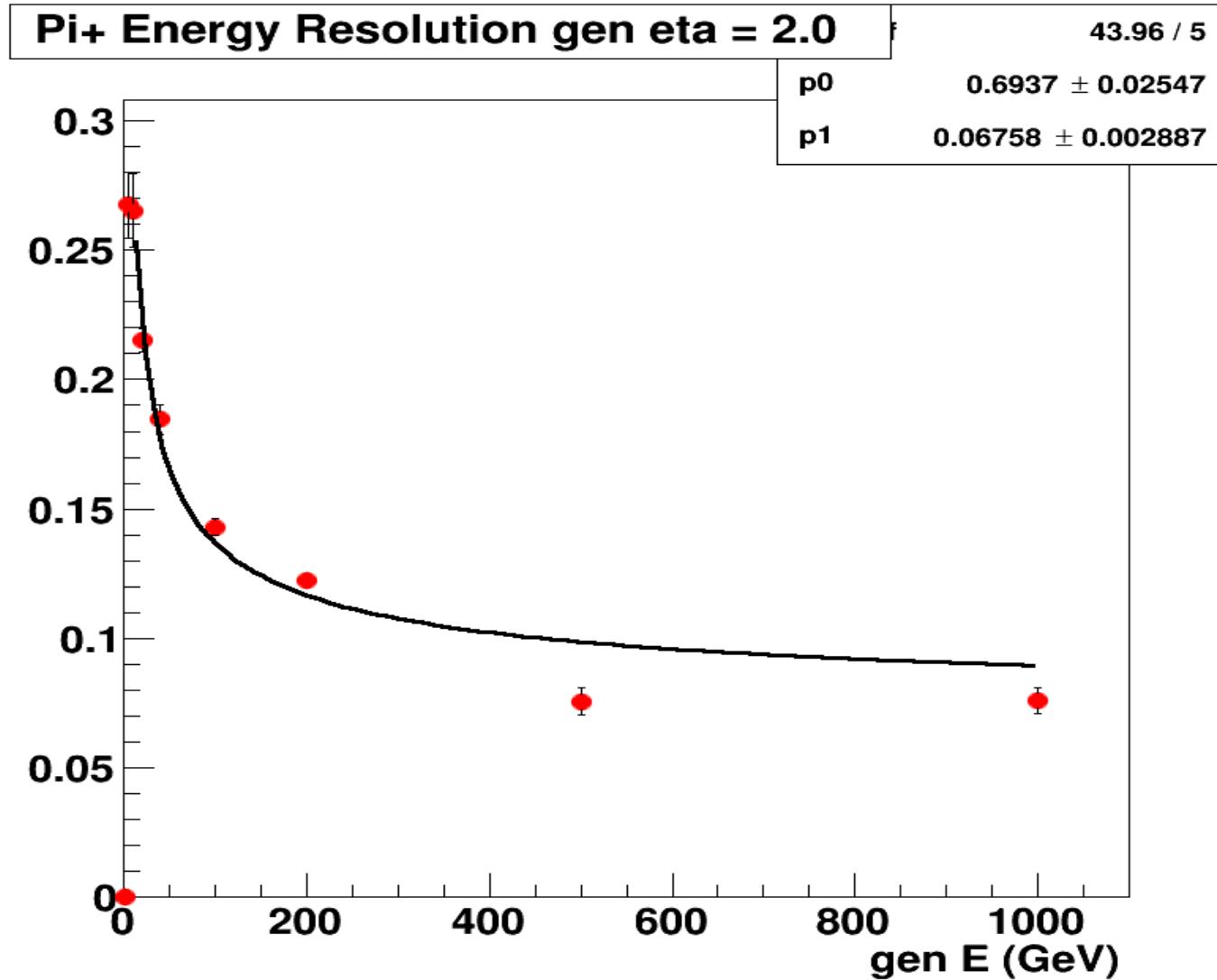


Pi+ Energy Linearity



Generator eta of pi+	Energy scaling (slope) (%)	Reco energy offset (intercept) (GeV)	Fit chi^2/NDF that determines E scaling
1.75	88.5 +/- 0.2	-3.66 +/- 0.06	374/5
2.0	88.1 +/- 0.2	-4.02 +/- 0.062	397/5
2.25	87.2 +/- 0.2	-4.42 +/- 0.07	510./5
2.5	86.7 +/- 0.2	-4.76 +/- 0.07	457/5
2.9	78.7 +/- 0.2	-7.10 +/- 0.12	437/5

Pi+ Energy Resolution



Pi+ Energy Resolution



Generator eta of Pi+	Stochastic energy resolution (%)	Constant energy resolution (%)	Fit chi^2/NDF that determines E resolution %
1.75	60.8 +/- 2.1	8.09 +/- 0.30	53.2/5
2.0	69.4 +/- 2.5	6.76 +/- 0.29	44.0/5
2.25	70.1 +/- 2.1	6.43 +/- 0.23	66.4/5
2.5	68.1 +/- 2.4	6.75 +/- 0.26	33.9/5
2.9	93.7 +/- 3.0	6.98 +/- 0.30	50.3/4

Conclusions



- Neutral K_long stochastic energy resolution $\sim 70\%$, constant energy resolution $\sim 6\%$
- Neutral K_long energy linearity $\sim 90\%$, offset $\sim -4 \text{ GeV}$
- Pi+ stochastic energy resolution $\sim 70\%$, constant energy resolution $\sim 7\%$, and large χ^2/NDF
- Pi+ energy linearity $\sim 90\%$, offset $\sim -4 \text{ GeV}$
- Rapid degradation in hadron energy resolution as $\eta \rightarrow 2.9$
- Future work:
 -
 -

Lingering Qs and Future Work

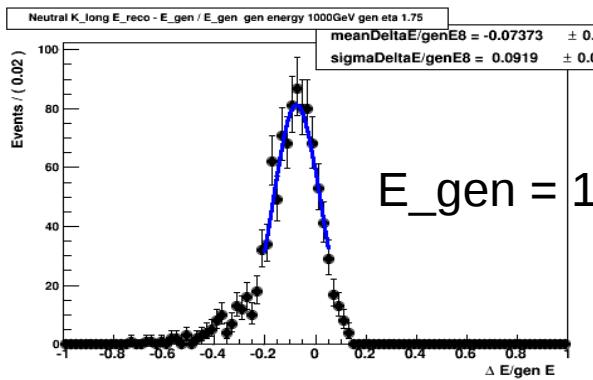
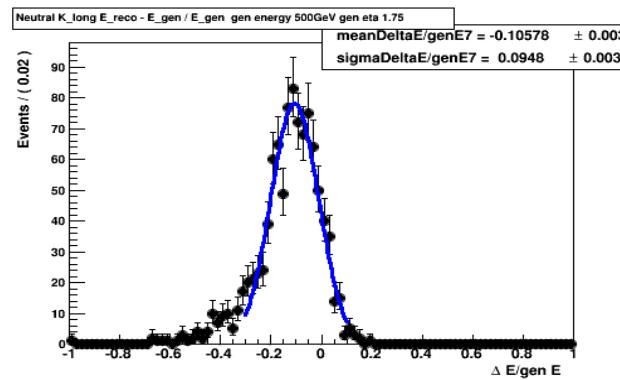
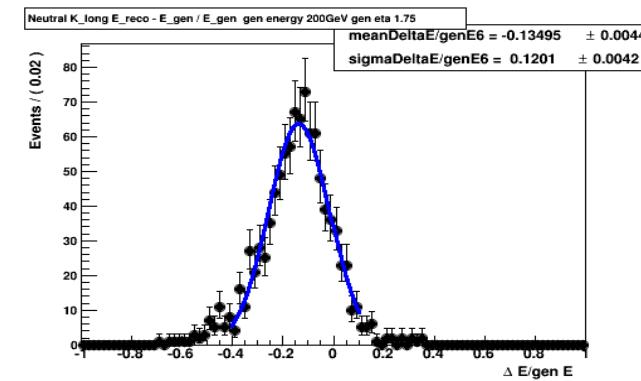
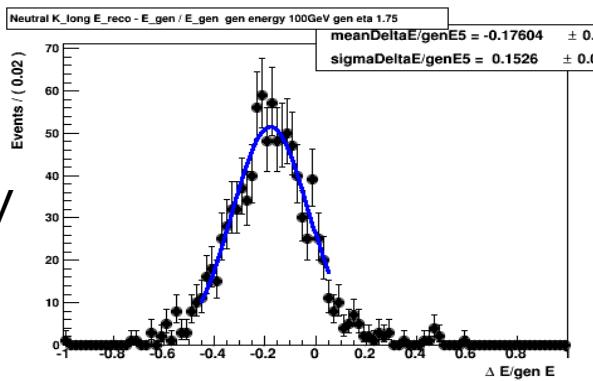
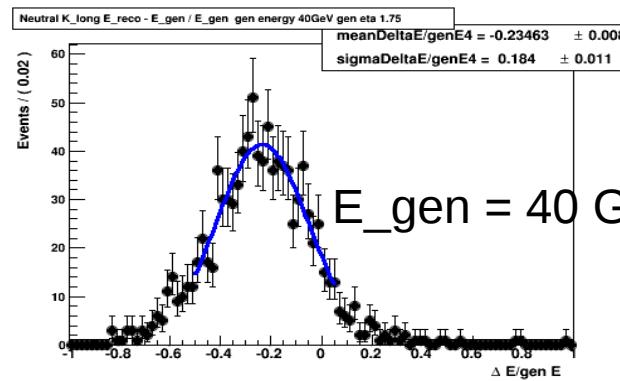
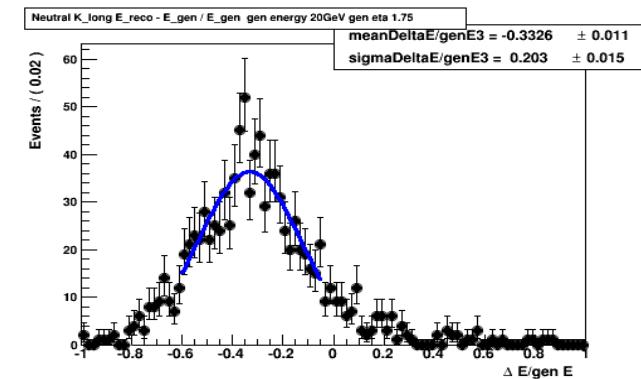
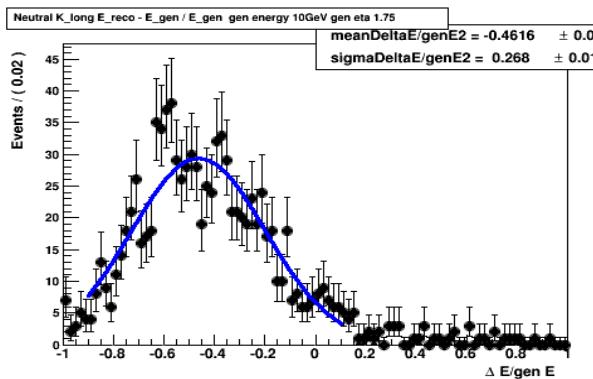
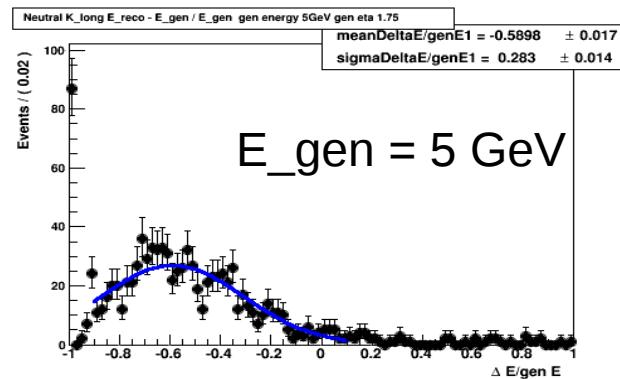


- Are E calibration constants similar for E/gamma PF objects?
- Future work:
 - Investigate Pi+ energy resolution with tracker measurements
 - Recalculate Pi+ and K_long energy resolution with correct neutron moderator
 - Look at fraction of reco energy deposited in back HE vs generator energy
 - Explore how PFCluster energy calibration is effecting E_reco (calibration varies between HGC subdetectors)
 - Investigate pi+ events with E_reco = 0 (most at very low pT) in event display
 - Plot E_HCAL/E_ECAL for pi+ as a fxn of generator E and eta

Backup



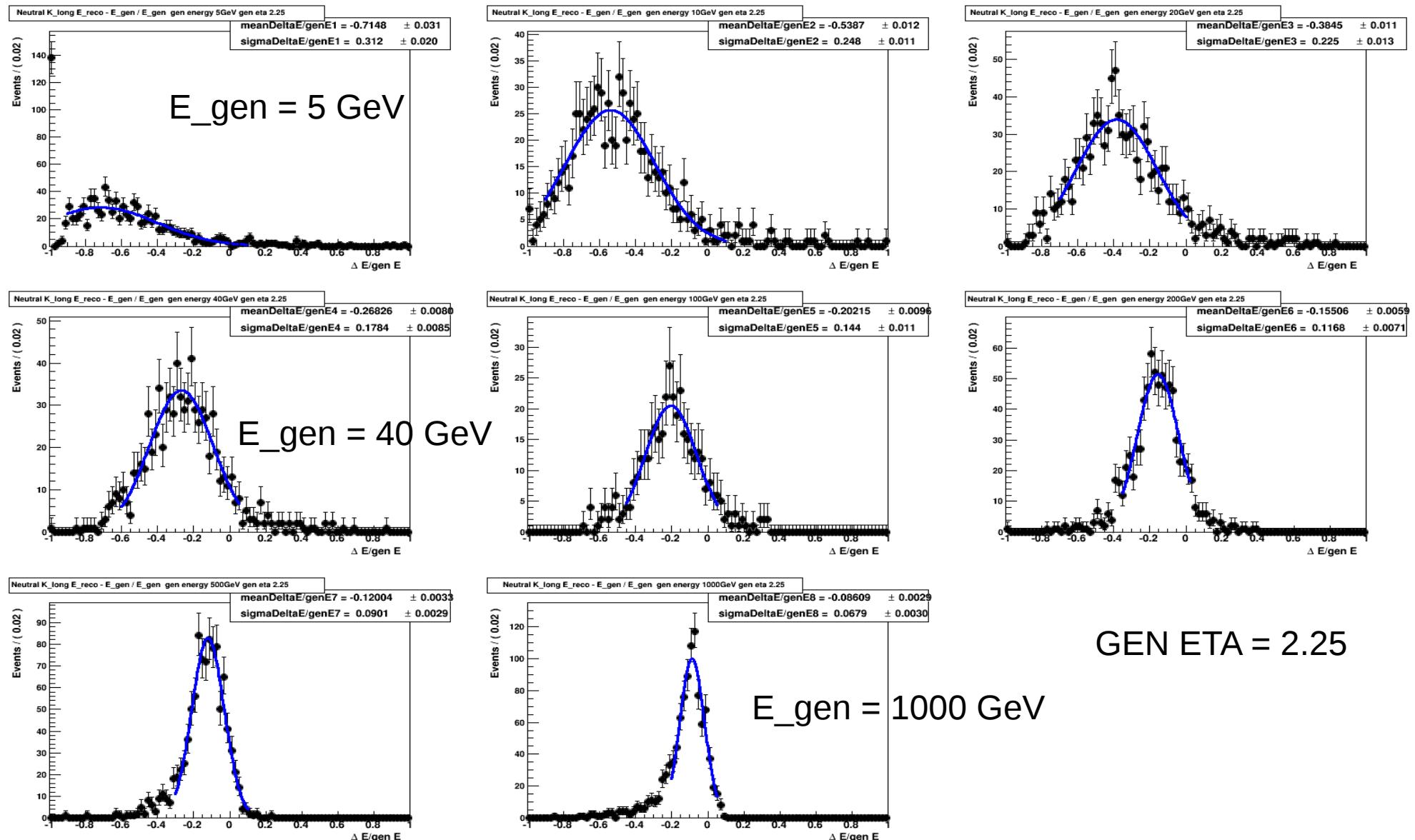
K0L $(E_{\text{reco}} - E_{\text{gen}})/E_{\text{gen}}$



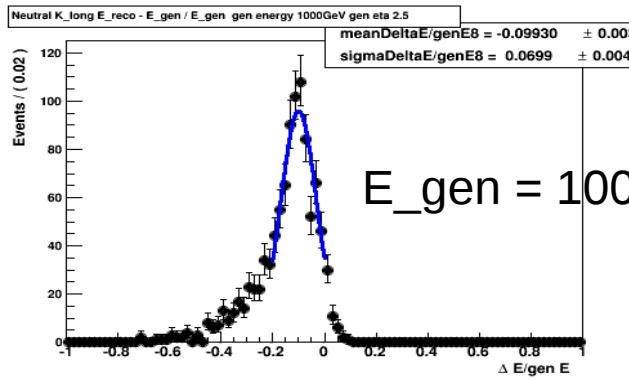
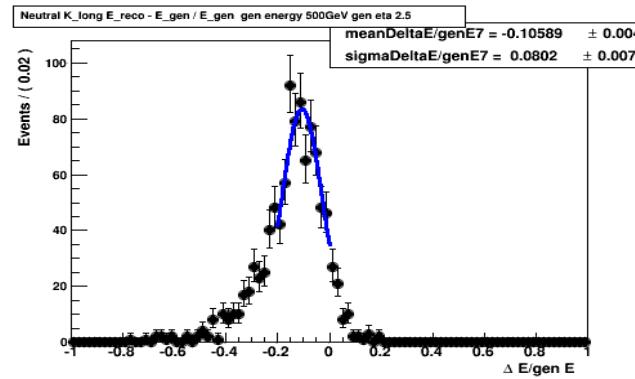
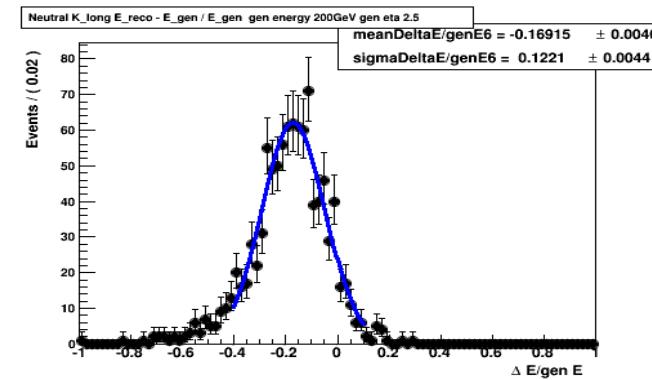
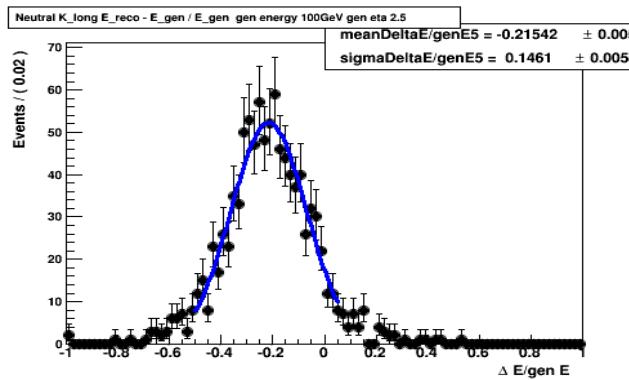
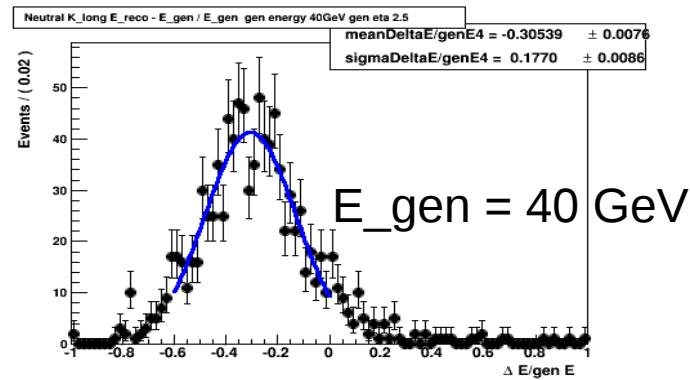
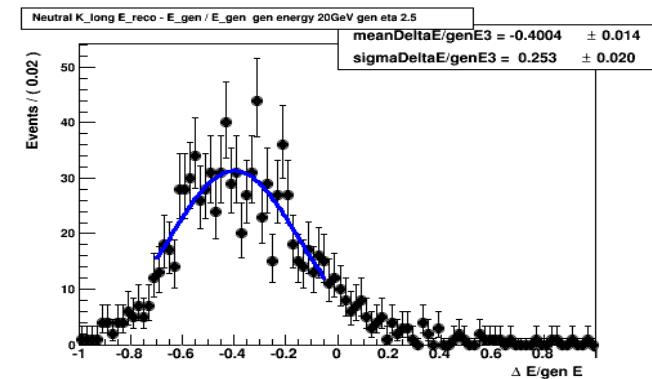
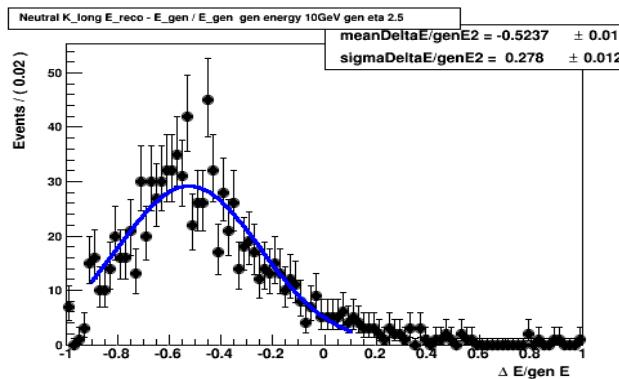
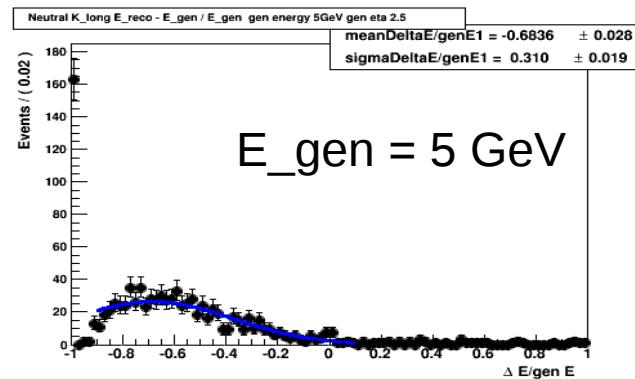
GEN ETA = 1.75

$E_{\text{gen}} = 1000 \text{ GeV}$

K0L $(E_{\text{reco}} - E_{\text{gen}})/E_{\text{gen}}$

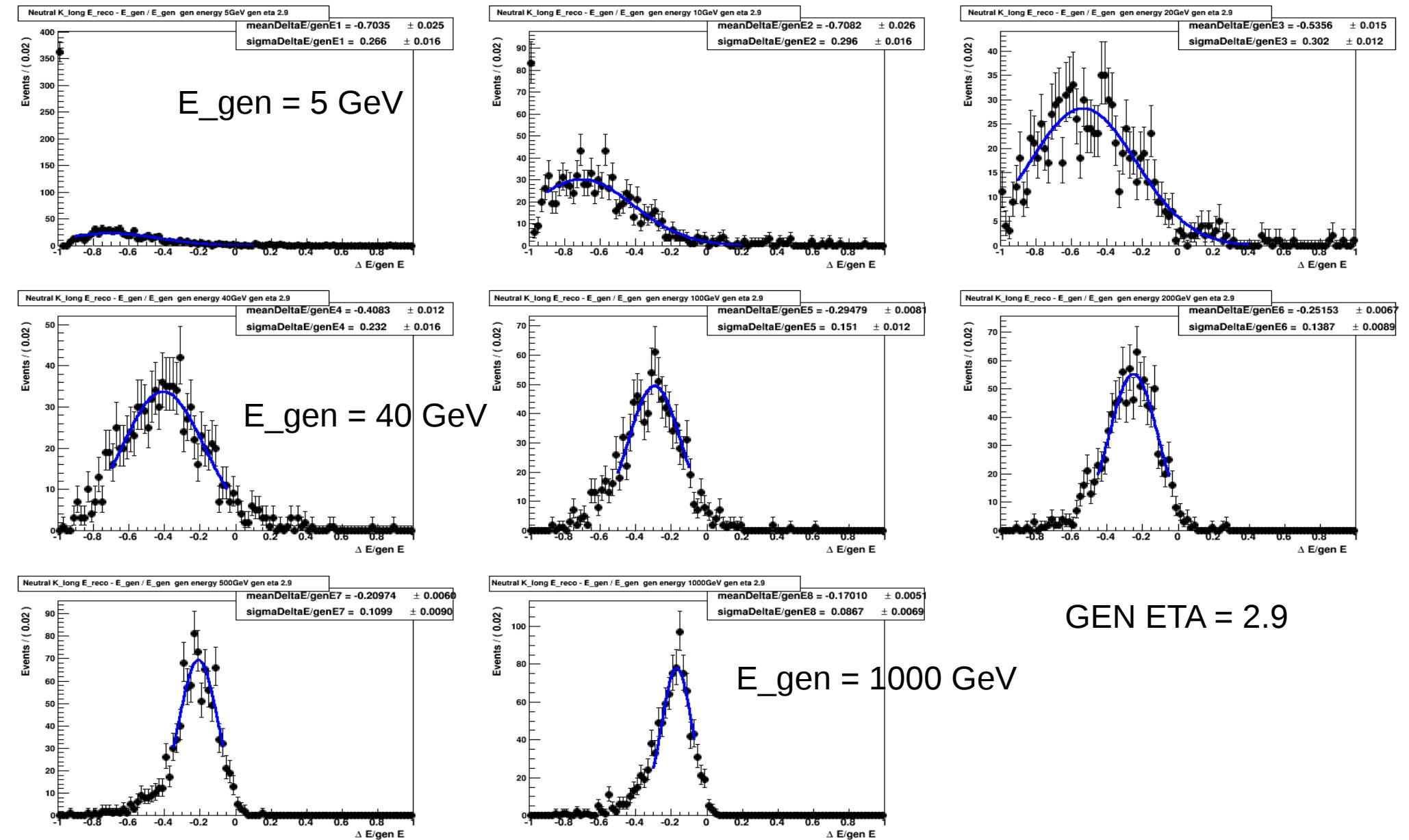


K0L $(E_{\text{reco}} - E_{\text{gen}})/E_{\text{gen}}$

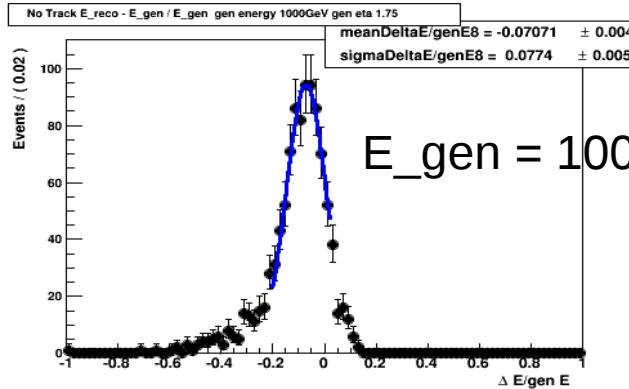
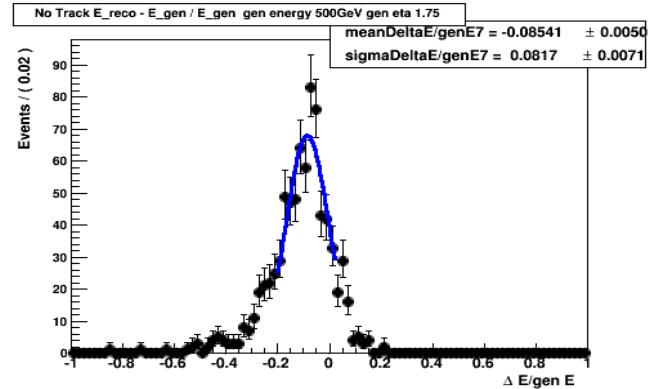
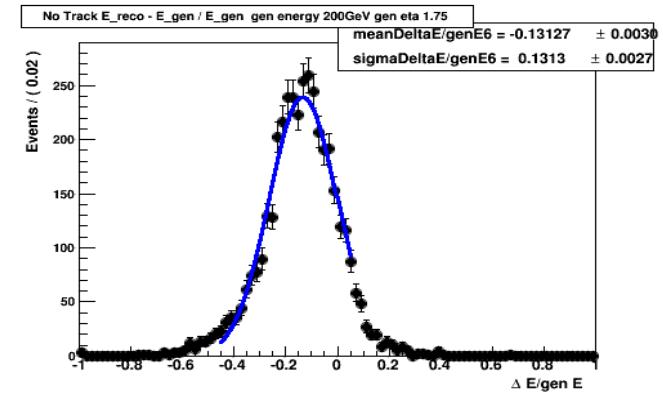
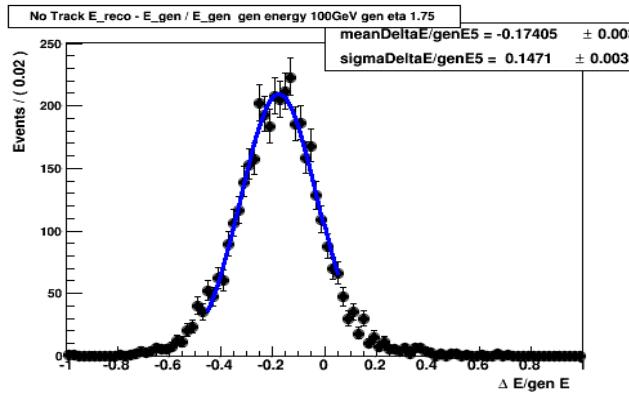
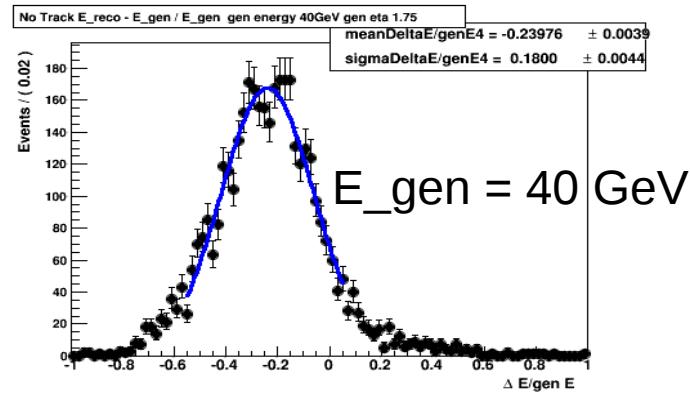
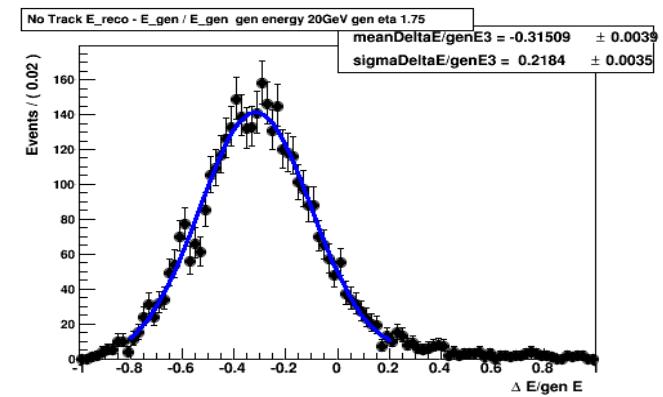
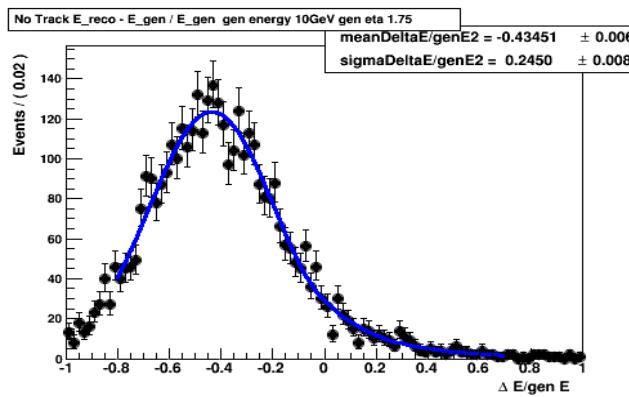
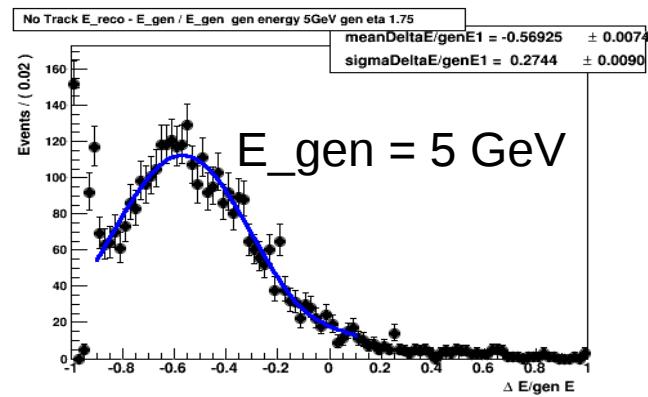


GEN ETA = 2.5

K0L $(E_{\text{reco}} - E_{\text{gen}})/E_{\text{gen}}$

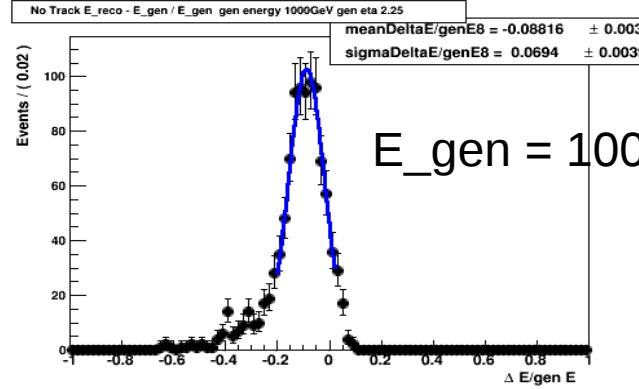
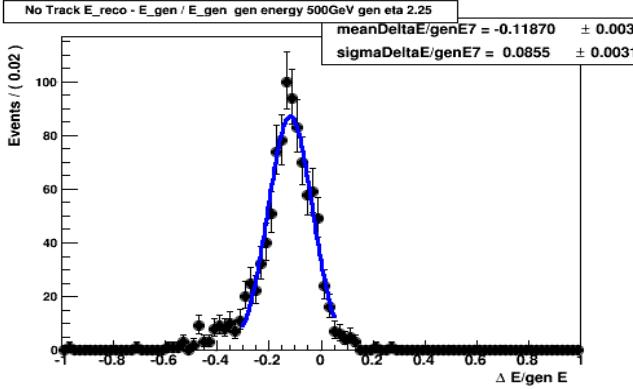
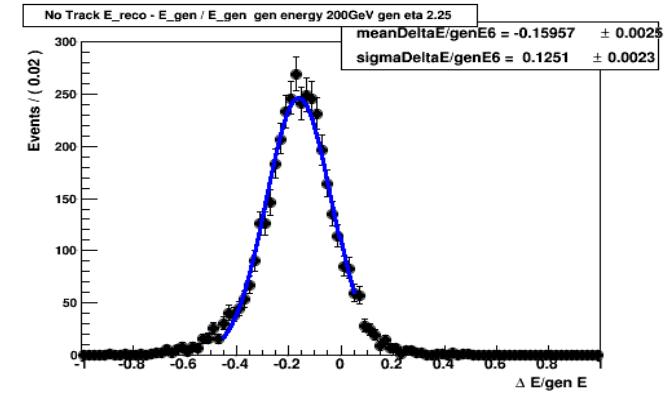
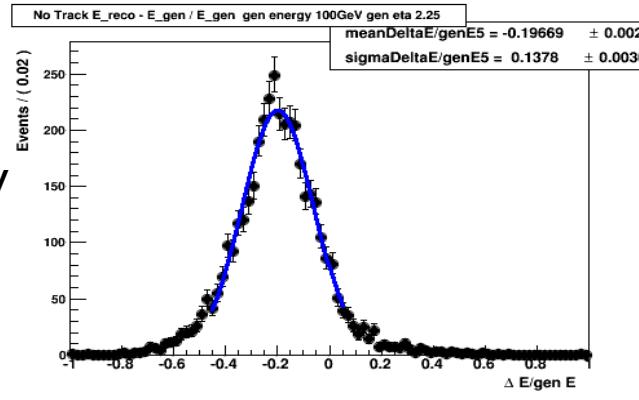
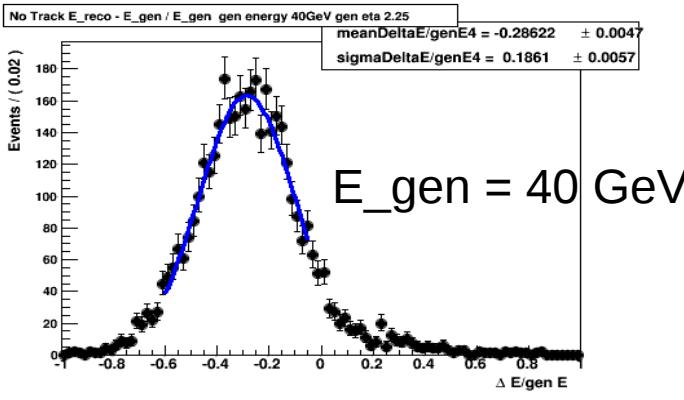
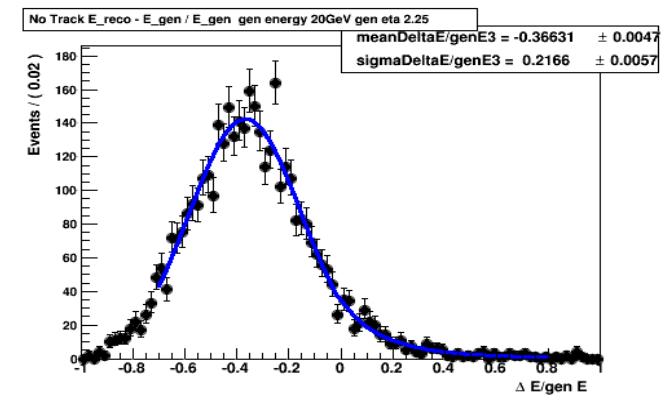
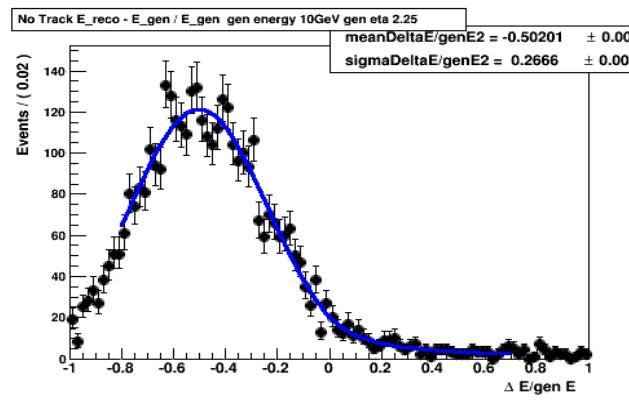
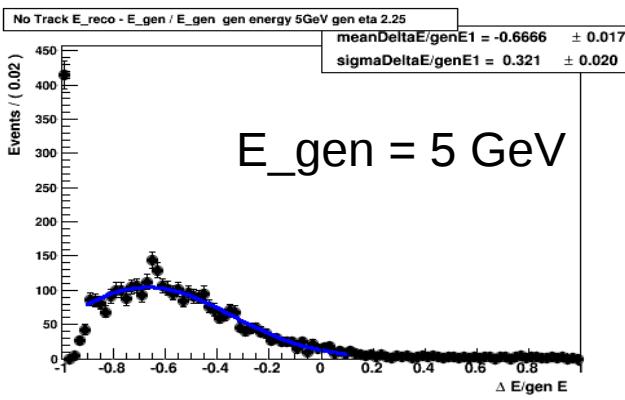


Pi+ ($E_{\text{reco}} - E_{\text{gen}}$) / E_{gen}



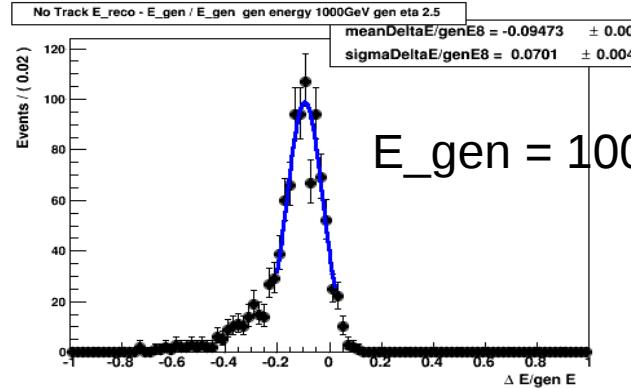
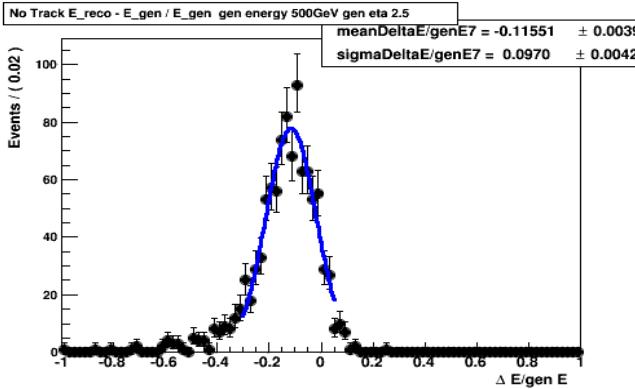
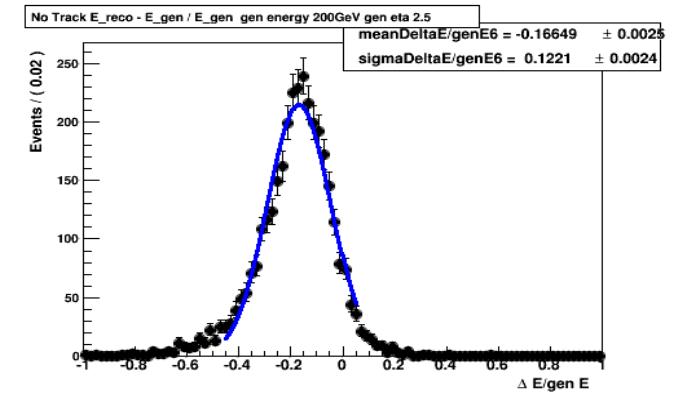
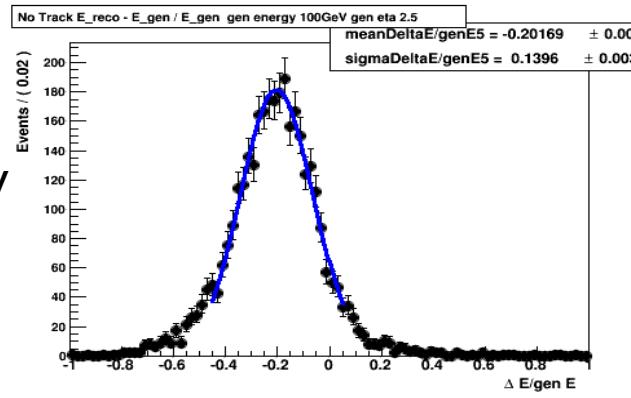
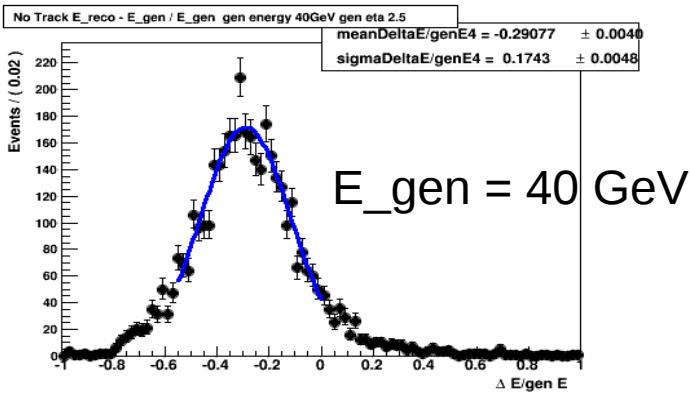
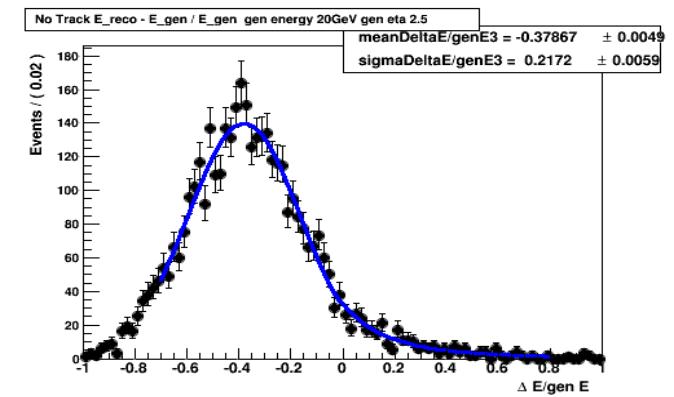
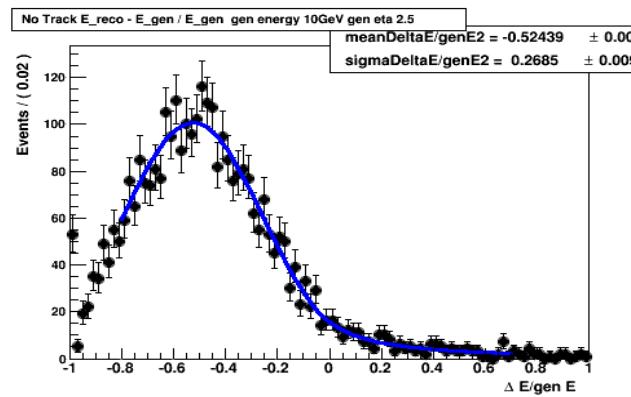
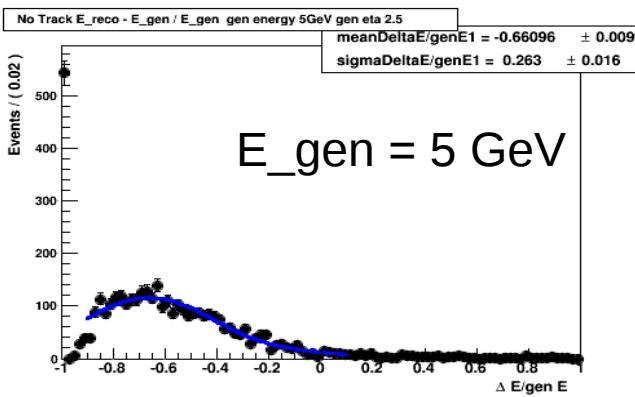
GEN ETA = 1.75

Pi+ ($E_{\text{reco}} - E_{\text{gen}}$) / E_{gen}



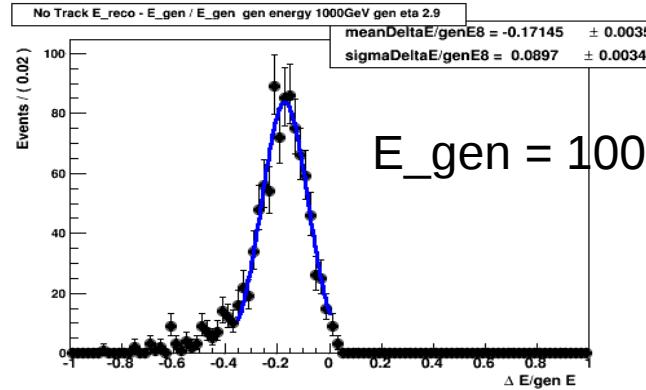
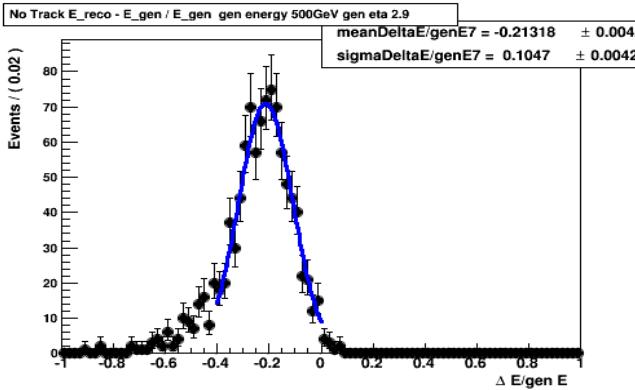
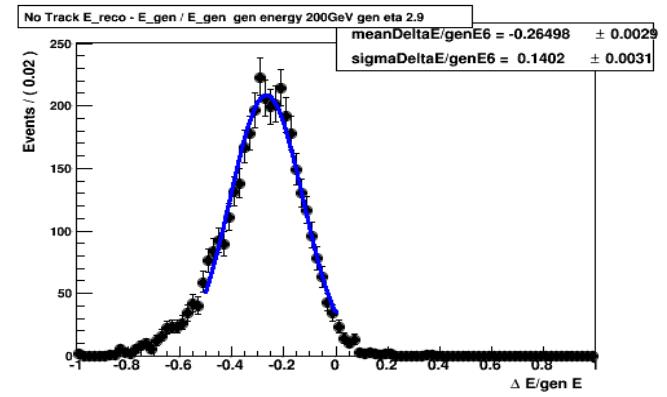
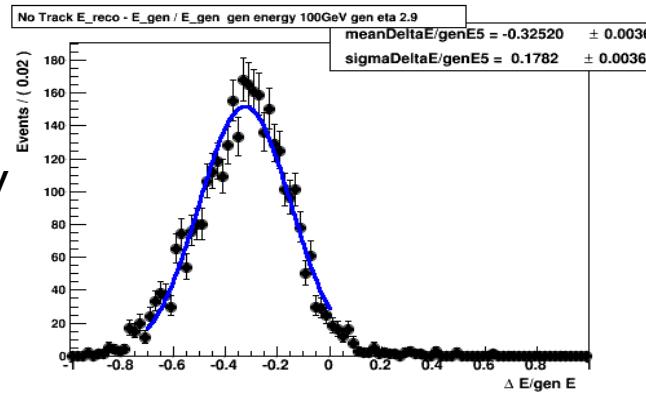
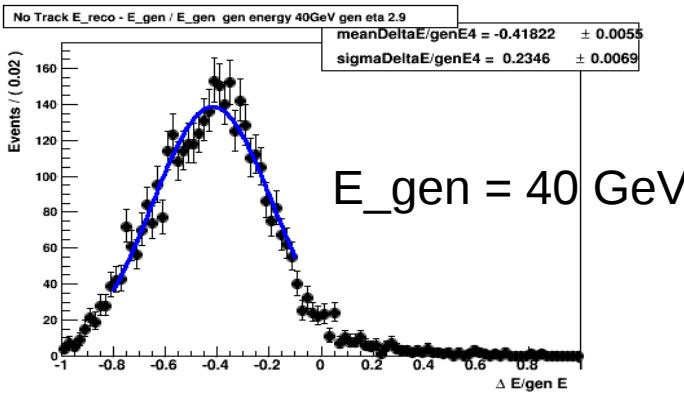
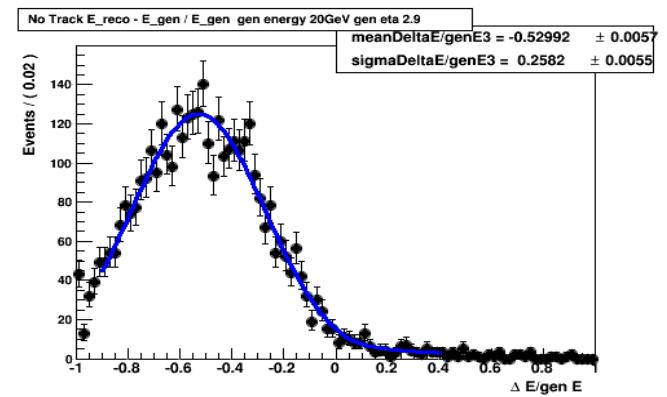
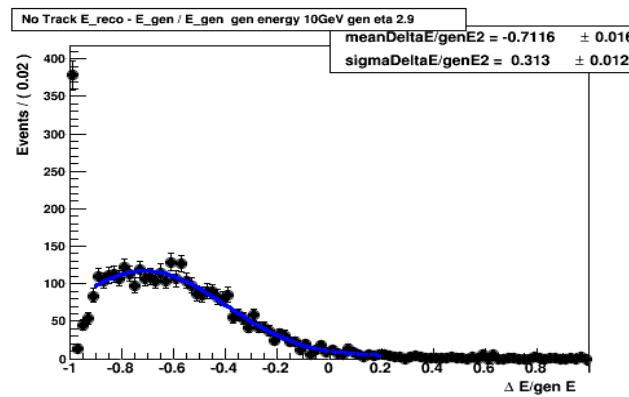
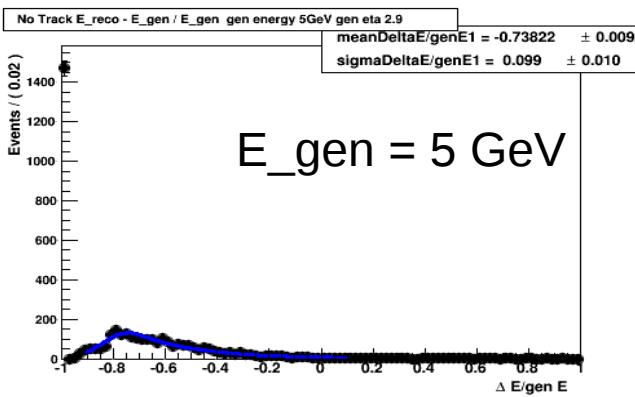
GEN ETA = 2.25

Pi+ ($E_{\text{reco}} - E_{\text{gen}}$) / E_{gen}



GEN ETA = 2.5

Pi+ ($E_{\text{reco}} - E_{\text{gen}}$) / E_{gen}



GEN ETA = 2.9